24 Virtual Plants: Process Simulation and Emulation

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INTRODUCTION

Recently customers' needs have become diversified because of high living standards and expectations coupled with individualism and consumerism. Consequently, suppliers find it harder to keep their products in the marketplace due to consumer behavior and intense competition. Industries such as the automobile industry, the automobile parts industry, the electrical machinery industry, and so on intensely feel the need to design and make new products for the market in rapid succession. Especially in Japan, these tendencies are becoming remarkably prominent.

As manufacturing systems are being created on larger and more complicated scales than ever before, it is very important to design and evaluate the manufacturing systems considering multi-purposes, multi-evaluation items, multi-viewpoints, suitable investments, total optimum conditions, and so on. It is also important to reduce lead time for manufacturing engineering processes from manufacturing system design to manufacturing system implementation phases.

One of the solutions to realize these requirements is simulation technologies, which find problems in advance and solve the problems at an earlier phase in the manufacturing engineering processes while limiting wasteful periods to minimum by reducing the number of times needed to go back and refine designs. The simulation technologies have attracted the attention of the industries with the advance of technologies such as computer calculation performance and three-dimensional computer-aided design (3D-CAD) information technologies.

MANUFACTURING SYSTEM ENGINEERING PROCESS

Based on our analysis for the typical manufacturing engineering processes, manufacturing systems are established through four phases. Figure 24.1 shows the typical manufacturing engineering processes.

1. *Phase 1:* It is the planning phase to define fundamental manufacturing requirements such as target production volumes, location, etc.
2. *Phase 2:* It is the manufacturing system design phase to fix manufacturing specifications such as the numbers of equipment needed, layout, production management with the Kanban system, and so on.
3. *Phase 3:* It is the manufacturing system implementation phase to establish the manufacturing system in response to the manufacturing specifications.
    a. *Phase 3.1:* This is a period prior to the manufacturing system implementation phase. In this period, engineers implement hardware such as special machines, transfer machines, and software such as ladder programs, robot programs, operation panels, and production control programs.
    b. *Phase 3.2:* This is a later period of the manufacturing system implementation phase. In this period, in order to undertake the manufacturing system trial operations, engineers partially operate hardware execution and software execution and accurately evaluate their executions from the viewpoints of the manufacturing systems.
4. *Phase 4:* It is the actual manufacturing system execution phase.

In phase 2, manufacturing system simulation technologies play important roles for designing and evaluating manufacturing systems by using virtual factory models. In phase 3, manufacturing system emulation technologies play important roles in constructing and evaluating manufacturing systems by using virtual factory models.

The main purpose of the manufacturing system simulation is to support creation and decision of the manufacturing specifications such as the numbers of equipment needed, layouts, and production managements. Several alternative ideas are evaluated using the manufacturing system simulation and the best idea is selected.

The main purposes of the manufacturing emulation are to make and improve control programs such as ladder programs and robot programs, and to guarantee interoperability between equipment, the control programs, and management applications. Using the manufacturing system simulation and emulation, wasteful periods are limited to minimum by reducing the number of times needed to go back and refine the designs.

Then, lead time for manufacturing engineering processes from the manufacturing system design phase to the manufacturing system implementation phase is reduced.

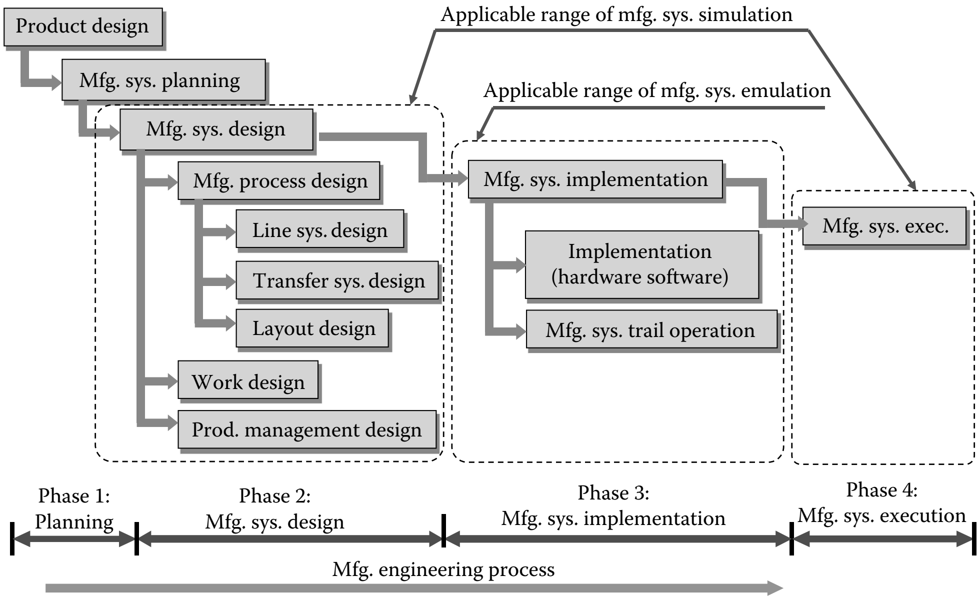


FIG. 24.1
Manufacturing engineering process.

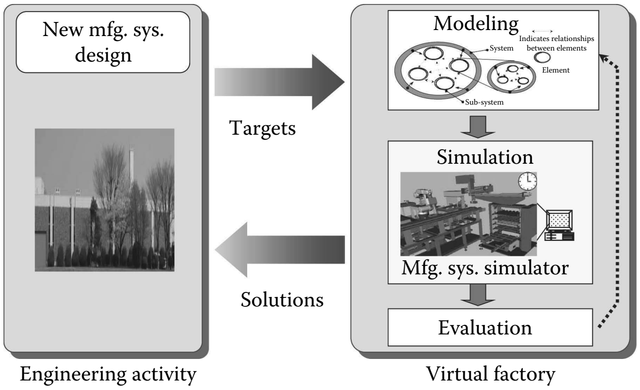


FIG. 24.2
Manufacturing system simulation.

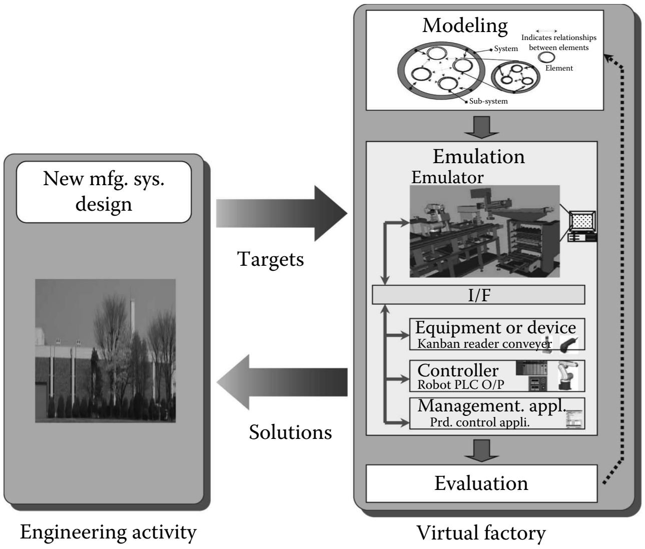


FIG. 24.3
Manufacturing system emulation.

The terms of the manufacturing system simulation, the manufacturing system emulation, and manufacturing system emulator are defined as follows:

1. Manufacturing system simulation means to create certain conditions of manufacturing systems by means of models. One of the main purposes of the manufacturing system simulation is to evaluate material flow and information flow. A simulation is executed while paying attention to particular events of interest, which occur at an instant, such as equipment start, equipment stop, and so on. Figure 24.2 shows an outline of the manufacturing system simulation.
2. Manufacturing system emulation means that under a condition where parts of equipment, control programs, and production management applications are not provided in the system, the system operates by mixing and synchronizing the emulators, real equipment, real controllers, and production management applications. Figure 24.3 shows an outline of the manufacturing system emulation.
3. A manufacturing system emulator is a device or piece of software that enables a program or an item of equipment intended for one type of computer or equipment to be used with exactly the same results with another type of computer or equipment.

Figure 24.4 shows an image of a manufacturing engineering process using the manufacturing system simulation and emulation.

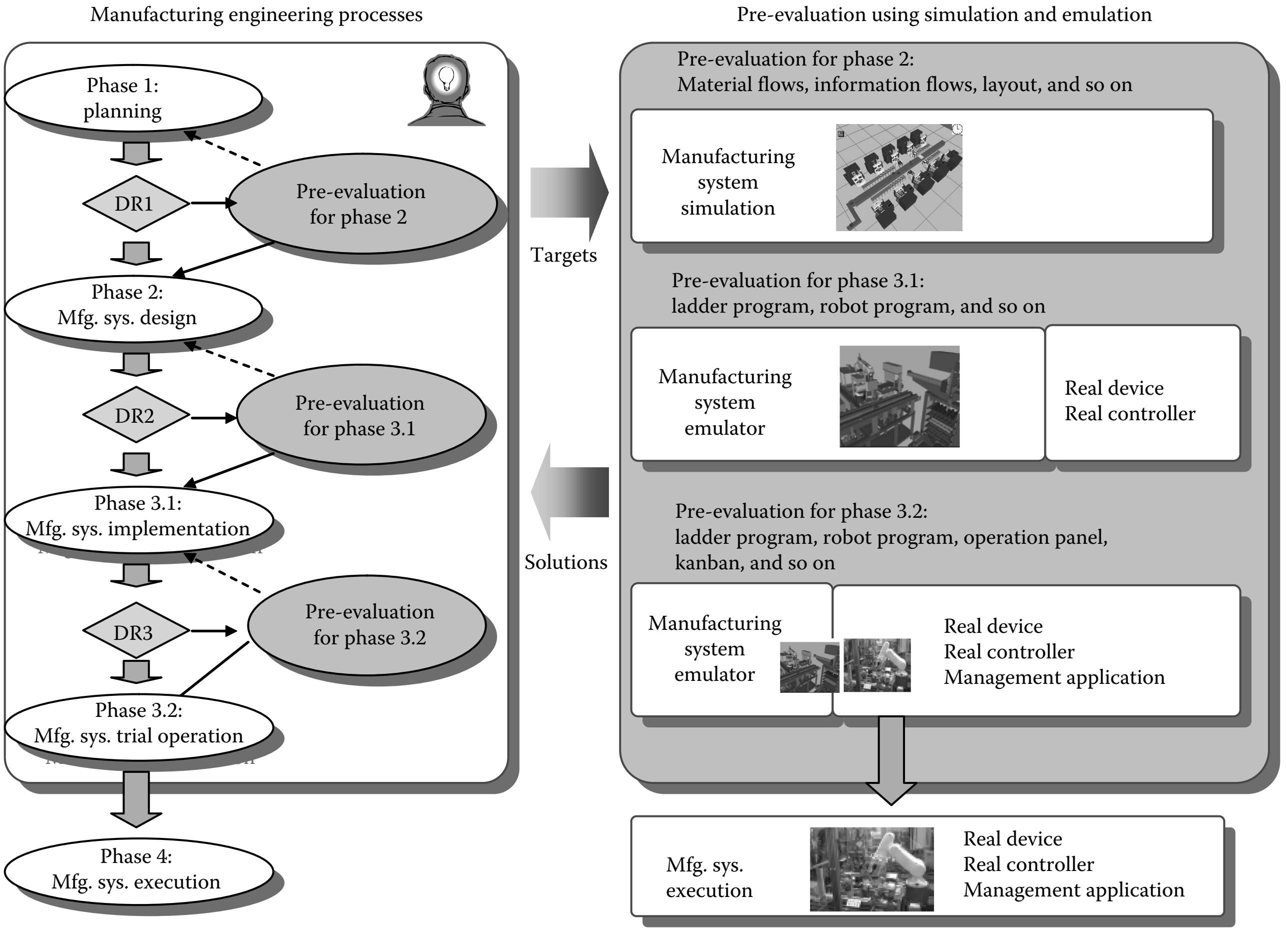

Manufacturing engineering processes
Pre-evaluation using simulation and emulation
Phase 1: planning
DR1
Pre-evaluation for phase 2
Phase 2: Mfg. sys. design
DR2
Pre-evaluation for phase 3.1
Phase 3.1: Mfg. sys. implementation
DR3
Pre-evaluation for phase 3.2
Phase 3.2: Mfg. sys. trial operation
Phase 4: Mfg. sys. execution
Targets
Solutions
Pre-evaluation for phase 2: Material flows, information flows, layout, and so on
Manufacturing system simulation
Pre-evaluation for phase 3.1: ladder program, robot program, and so on
Manufacturing system emulator
Real device
Real controller
Pre-evaluation for phase 3.2: ladder program, robot program, operation panel, kanban, and so on
Manufacturing system emulator
Real device
Real controller
Management application
Mfg. sys. execution
Real device
Real controller
Management application

FIG. 24.4
Manufacturing engineering process using simulation and emulation.

The following procedure shows the typical activities using the manufacturing system simulation and the emulation:

1. Creation and decision of targets to be solved using the manufacturing system simulation/emulation
2. Modeling for the targets
3. Construction of a simulation/emulation program in response to the modeling
4. Execution of simulation/emulation for the program
5. Evaluation of results of simulation/emulation
6. Decision of actions in response to the best results of simulation/emulation

Figure 24.5 shows an outline of the procedure using the manufacturing system simulation and the manufacturing system emulation.

MANUFACTURING SYSTEM SIMULATION IN MANUFACTURING SYSTEM DESIGN PHASE

In the system design phase, the manufacturing system is designed by input information, which is product design information based on production drawings and CAD data and guarantees of quality, and manufacturing information based on production volumes, varieties of products, and production periods in the market. During the manufacturing system design phase, past manufacturing system specifications such as similar manufacturing processes, similar structures of the manufacturing system, and the detailed specifications are referred to. Design policies such as concepts, fundamental objectives, permissible capital investments, due date, restrictions are also referred. As final results of the manufacturing system design, manufacturing system specifications such as manufacturing processes to produce, structures of the manufacturing system, and detailed specification for the structures are defined.

The specifications of the processes to produce define manufacturing processing methods, sequences of manufacturing processing, and so on. For example, in order to produce a product, the specifications describe what kinds of processes and manufacturing sequences are needed.

The specifications of the structures of the manufacturing system define roles of systems in a manufacturing system, fundamental specifications, and structures of machining

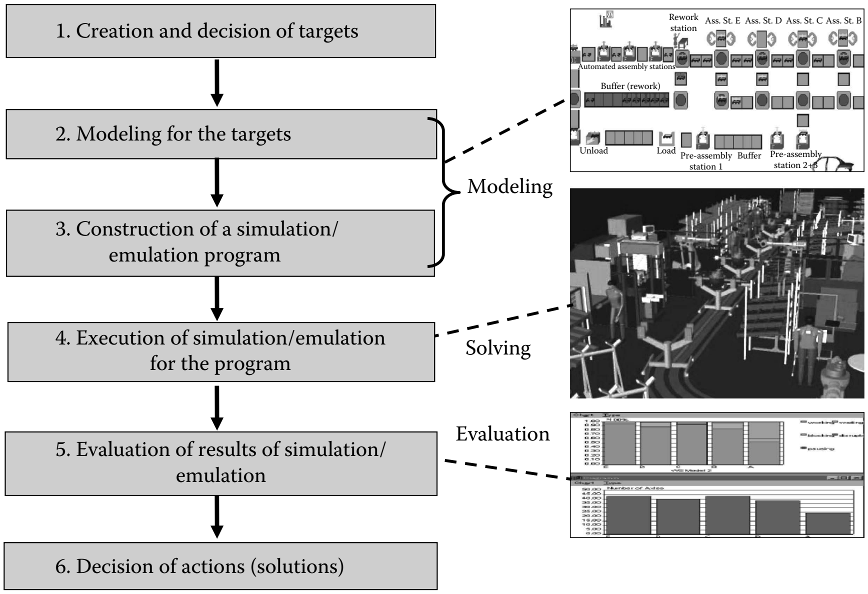

1. Creation and decision of targets
2. Modeling for the targets
3. Construction of a simulation/ emulation program
4. Execution of simulation/emulation for the program
5. Evaluation of results of simulation/ emulation
6. Decision of actions (solutions)
Modeling
Solving
Evaluation
Rework station
Ass. St. E
Ass. St. D
Ass. St. C
Ass. St. B
Automated assembly stations
Buffer (rework)
Unload
Load
Pre-assembly station 1
Buffer
Pre-assembly station 2+3

FIG. 24.5
Procedure for simulation and emulation.

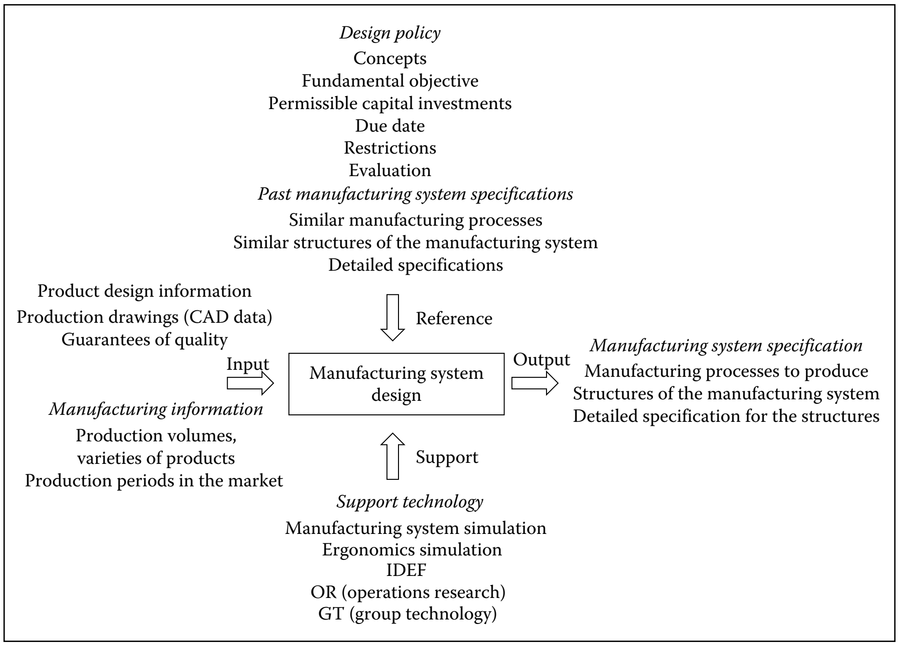

Design policy
Concepts
Fundamental objective
Permissible capital investments
Due date
Restrictions
Evaluation
Past manufacturing system specifications
Similar manufacturing processes
Similar structures of the manufacturing system
Detailed specifications
Reference
Product design information
Production drawings (CAD data)
Guarantees of quality
Input
Manufacturing system design
Output
Manufacturing system specification
Manufacturing processes to produce
Structures of the manufacturing system
Detailed specification for the structures
Manufacturing information
Production volumes,
varieties of products
Production periods in the market
Support
Support technology
Manufacturing system simulation
Ergonomics simulation
IDEF
OR (operations research)
GT (group technology)

FIG. 24.6
Manufacturing system design.

lines systems, assembly lines systems, transfer systems, and production management systems. For example, the specifications describe layouts of each system, types of the transfer system, target throughput, and so on.

The detailed specifications for the structures clearly define elements of line systems, transfer systems, and production management systems. For example, the specifications describe equipment in a machining line system in response to processing methods, and the number and type of equipment in the machining line system such as milling machines, conveyors, and so on.

The manufacturing system simulation plays important roles to define the system specifications while evaluating material flow and information flow in a factory. Figure 24.6 shows an outline of manufacturing system designs. Figure 24.7 shows an image of material flow and information flow in a factory.

Currently, there is no formulation for manufacturing system designs. Based on our analysis for the typical manufacturing system designs, the manufacturing system designs are established as Figure 24.1.

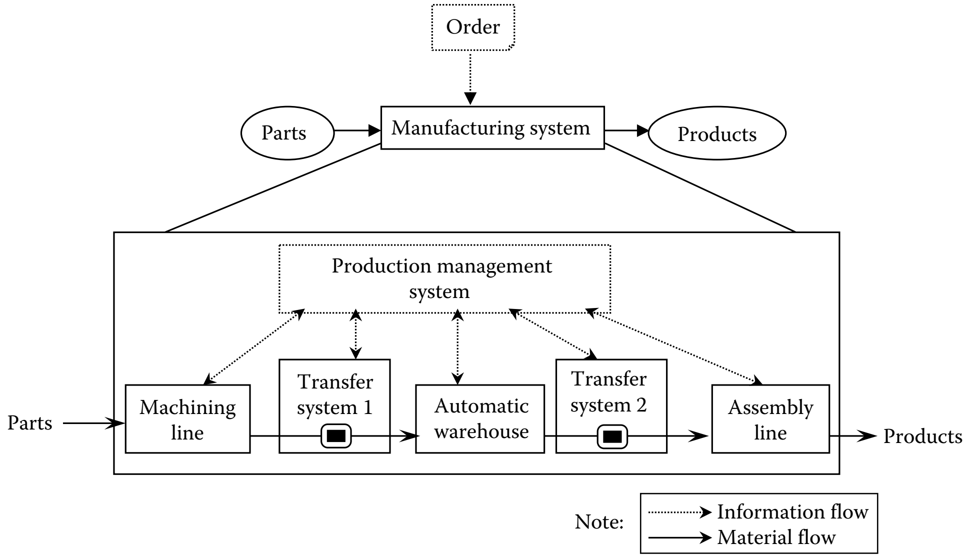


FIG. 24.7
Material flow and information flow in factory.

In the manufacturing design phase, there are mainly three design processes as the manufacturing process design, the work design, and the production management design.

In the process design, the manufacturing processes to produce, structures of manufacturing system, and detailed specification for the structures are created and evaluated. The process design is the core of the manufacturing system design phase.

In the work design, tasks in equipment, labors, and line systems are designed. For example, concerning work designs for machining, the following items are defined:

- Definition of machining process
- Definition of conditions for machining
- Selection of machining tools
- Selection of fixture to hold parts or pieces of works

In the production management design, production management methods are defined such as the push-type production control system and the pull-type production control system. The push-type production control system is based on making to stock in which the production is not based on actual demand. The pull-type production control system is based on making to order in which the production is based on actual demand as just-in-time (JIT) system.

In the manufacturing design phase, especially, the system simulation often plays important roles on the manufacturing process design. Therefore, the usages of the manufacturing system simulation in the manufacturing process design are described in detail.

In the manufacturing process design, there are mainly three types: the line system design, the transfer system design, and the layout design as in Figure 24.1. These three designs are often operated concurrently.

Line System Design

First, the line system design is discussed in detail.

In the line system design, typical line systems are classified into three types, which depend on production volumes and varieties of products. These types are the low-variety high-volume manufacturing, the middle-variety middle-volume manufacturing, and the high-variety low-volume manufacturing.

With the low-variety high-volume manufacturing, the transfer-type line systems are often used. Locations for equipment in the transfer-type line systems are sequentially arranged in response to machining processes and assembly processes.

Parts for the machining processes and the assembly processes flow to one way and are processed in sequence by the equipment. For example, in the transfer-type line systems for machining such as the automobile engine parts, the single function machining, which are sequentially arranged, process the parts while transferring the parts by conveyors.

With the transfer-type line systems, tact time is defined as maximum time per unit allowed producing a product in order to fit demand. The tact time sets like the pace for the transfer-type line systems. For example, parts are assembled on equipment, and are moved on to the next equipment during a certain time. In this case, the time needed to complete work on equipment has to be less than the tact time in order for the product to be completed within the allowed time. However, statistics data of process time in equipment usually become dispersion. This dispersion causes stagnation for the material flow because of causing a blocking state and a starving state in equipment. To solve the stagnation, buffer functions, which store parts, are examined at the intermediate space

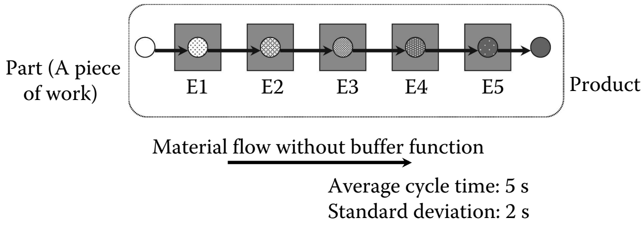


FIG. 24.8
Transfer line system without buffer function.

between equipment. The manufacturing system simulation is often used to evaluate the buffer functions.

The following show a typical example for stagnation for the material flow.

Figure 24.8 shows a hypothesis transfer-type line system that consists of five equipments. The tact time for the transfer-type line system is 5 s. Average cycle time in equipment sets 5 s. Standard deviation for the cycle time sets 2 s.

Figure 24.9 shows simulation model 1, which is modeled the hypothesis transfer-type line system by the manufacturing system simulator. There is no buffer function in the model 1. Then, as the results of the simulation, the average working rate in equipment is 86.3%. The reasons are the following. Figure 24.10 shows a typical stagnation. Equipment No.3 (E3) is a running state. A task of a part in equipment No.2 (E2) is finished. The part in E2 is waiting to be transferred to E3 until a task of a part in E3 is finished and transferred to equipment No.4 (E4). This occasion is defined the blocking state. E4 is an idle state because E4 is waiting for a next task for the part in E3 until the part in E3 is transferred to E4. This occasion is defined the starving state. In the model 1, the equipment often causes the blocking state and the starving state and increases the idle state.

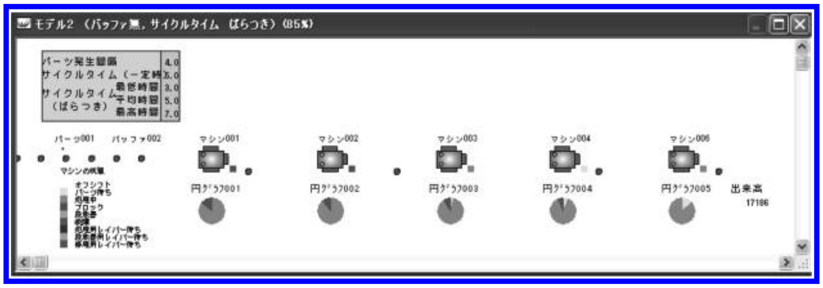
Figure 24.11 shows the transfer system with the buffer function. Figure 24.12 shows simulation model 2, which is modeled the transfer-type line system with the buffer function by the same simulator. In the model 2, there is one buffer function that is located on intermediate space between equipment. Each buffer function provides a space that keeps one part if the next equipment is the running state. Then, as the results of the simulation, the average working rate in equipment is 96.9%. Using the buffer function, we can see that the average working rate in equipment drastically increases. The appropriate buffer function is important to avoid stagnation for the material flow. The manufacturing system simulation supports to decide an appropriate buffer function. This example considers a simple line system. We can easily fine better solutions. However, line systems in industries are larger and more complicated scales than ever before. The manufacturing system simulation is often used to evaluate line systems and fine better solutions.

Using the manufacturing system simulation, the following items are mainly evaluated in the line system designs including transfer-type line system and flexible manufacturing system (FMS):

- Cycle time analysis
- Make-span (time-in system) analysis
- Bottleneck analysis
- Capacity of production such as the throughput, the working rates in equipment, the working rates of labors
- Flexibility and influence for setup changes in equipment in response to product volume or mix
- Influence for the proportion of breakdowns and maintenance in equipment
- Capital investments

Using the manufacturing system simulation, the following items are mainly determined in the line system designs including transfer-type line system and FMS:

- Number and type of machines such as machining and conveyors
- Number and type of support equipment such as pallets and fixtures
- Location and size of inventory buffers
- Number of labors
- Line system layout



パーツ発生間隔 4.0
サイクルタイム（一定時間）5.0
サイクルタイム（ばらつき） 最低時間 3.0
平均時間 5.0
最高時間 7.0

Input information

Average cycle time: 5 s
Standard deviation: 2 s

Output information

Average working rate: 86.3%

FIG. 24.9
Simulation model for transfer line system without buffer function.

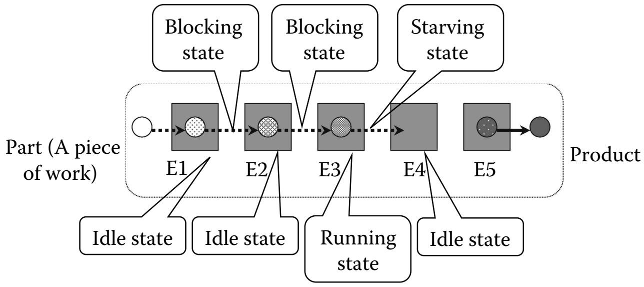


FIG. 24.10
Typical stagnation in transfer line system without buffer function.

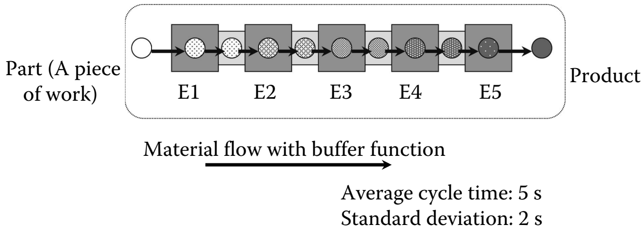


FIG. 24.11
Transfer line system with buffer function.

- Size of lots
- Target throughput
- Target tact time
- Procedure of manufacturing processes
- Frequency of preventive maintenance for equipment

With the middle-variety middle-volume manufacturing, the manufacturing system is required flexibility. With the machining shops, the FMS is familiar to realize the middle-variety middle-volume manufacturing. FMS allows the system to react in the case of changes, whether predicted or unpredicted. This flexibility is generally considered two characteristics. The first characteristic, machine flexibility, covers the system's ability to be changed to produce new product types, and ability to change the order of operations executed on a part. The second characteristic is called routing flexibility, which consists of the ability to use multiple equipment to perform the same operation on a part, as well as the system's ability to absorb large-scale changes, such as in volume, capacity, or capability.

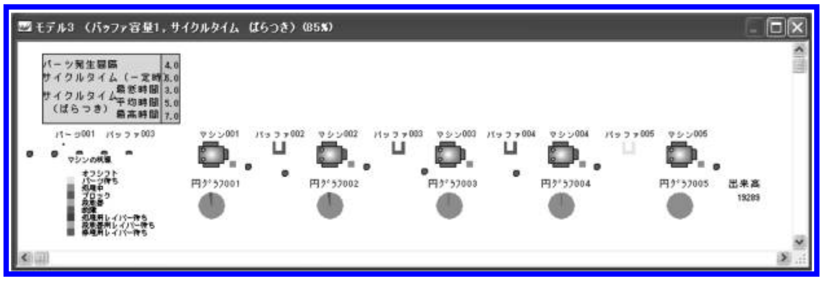
Most FMS systems consist of three main systems. The machining that is often automated computer numerical controlled (CNC) machining is connected by a material handling system to optimize part flow and the central control computer that controls material movements and equipment flow.

In order to design FMS, the manufacturing system simulation plays important roles. Figure 24.13 shows a simulation model that is modeled one of the typical FMS by the manufacturing system simulator. The FMS model consists of 10 CNC milling machines and 2 motor driving conveyors as the material handlings system. Typical evaluation items and determination items are shown in the previous sentences for the transfer-type line system.

With the high-variety low-volume manufacturing, the manufacturing system is required higher flexibility and reconfigurability. Many manufacturing systems are proposed. Especially in Japan, cell production systems are popular.

The *cell production* involves both machines and human workers. In conventional production, products were manufactured in separate areas and many workers would work on their own, as on the transfer-type line system. In the cell production, workers are organized into multiskilled teams. Each team is responsible for a particular part of the manufacturing process including quality control and safety. Each work cell is made up of one team that deliver finished items on to the next cell in the manufacturing process. The cell production can lead to efficiency improvements due to increased motivation and workers sharing their skills and expertise.

Currently, in order to design and evaluate the cell productions, the manufacturing system simulation is not often used because of difficulty to make the simulation models. Industries need to have suitable simulation technologies to support designing and evaluating the cell productions. The ergonomics simulation is examined in the academic level.



Input information

Average cycle time: 5 s
Standard deviation: 2 s

Output information

Average working rate: 96.9%

FIG. 24.12
Simulation model for transfer line system with buffer function.

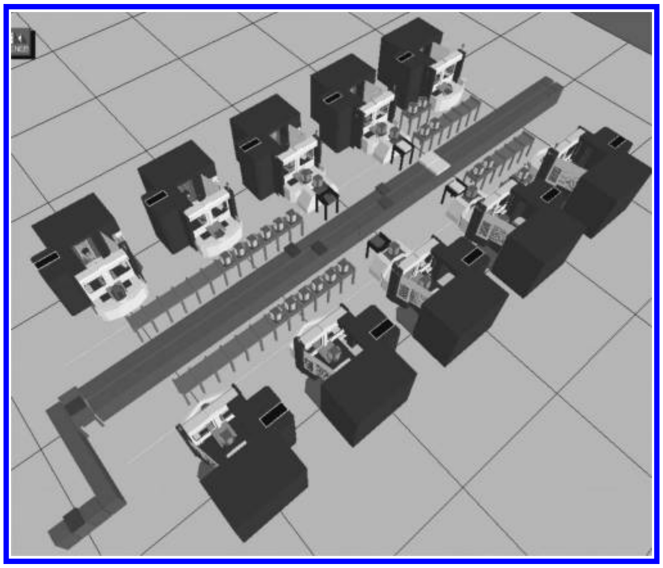


FIG. 24.13
Simulation model for FMS.

Transfer System Design

Transfer systems play important roles to connect material flows between line systems such as machining line systems and assembly line systems. In the manufacturing process design, it is important to consider total balance as a whole on the system. The transfer system is one of the key systems to realize total balance in the manufacturing system.

The transfer system is classified into two types as a continuous transfer system type and an intermittent transfer system type. Conveyors are typical continuous transfer systems. Auto guided vehicle (AGV) is most often used in the intermittent transfer system applications. AGV is a mobile equipment that follows markers or wires in the floor, or uses vision or lasers. As routes of AGVs can be easily changed, layouts of manufacturing system using AGV can be changed with flexibility in response to line system renewals. Therefore, AGVs are widely used in industries. In order to design and evaluate the transfer system, the manufacturing system simulation is often used.

The following examples illustrate a transfer system design.

Figure 24.14 shows a hypothesis manufacturing system that produces motors. Figure 24.15 shows structures of the motor. The manufacturing system mainly consists of an upper housing line system, an under housing line system, a rotor line system, a stator line system, an assembly line system, a storage facility that stores all parts including purchased parts, and a transfer system that connects with all systems. Figure 24.16 shows a simulation model for the transfer system using AGVs.

Using the manufacturing system simulation, the following items are mainly evaluated for the transfer system including the hypothesis example:

- Cycle time analysis
- Make-span (time-in system) analysis
- Bottleneck analysis
- Capacity of production such as the throughput, the working rates in AGVs, the working rates of labor
- Time parts spend waiting for transport
- Time parts spend in transport
- Influence for control strategies (e.g., for a conveyor system or an AGV system)
- Influence for transfer route

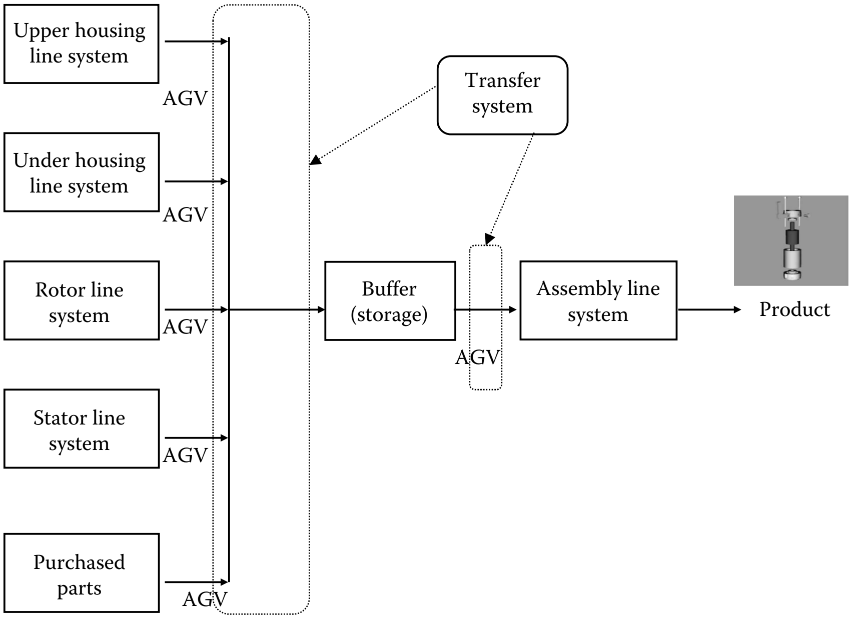


FIG. 24.14
Hypothesis manufacturing system to produce motors.

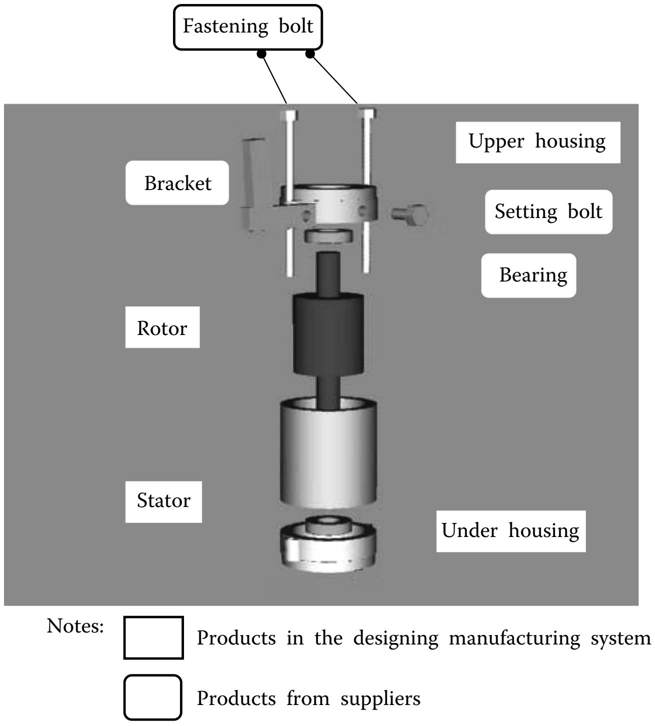


FIG. 24.15
Motor structures.

- Influence for transfer layout
- Influence for breakdowns and maintenance in AGVs
- Capital investments

Using the manufacturing system simulation, the following items are mainly determined for the transfer system including the hypothesis example:

- Control strategies (e.g., for a conveyor system or an AGV system)
- Transfer route
- Number of AGVs
- Number of the loading and unloading stations
- Location and size of inventory buffers
- Number of labors
- Transfer system layout
- Size of lots
- Frequency of preventive maintenance for AGVs

Layout Design

The purposes of the layout design are to determine arrangements of factory layouts considering several restrictions such as factory space, manufacturing process and material follows restrictions, labor resources, capital investments, and so on.

In the layout design, manufacturing system layouts are often determined considering line systems and transfer systems in a factory. The factory space is usually limited. The layout, which is lack of consideration, often, becomes causes

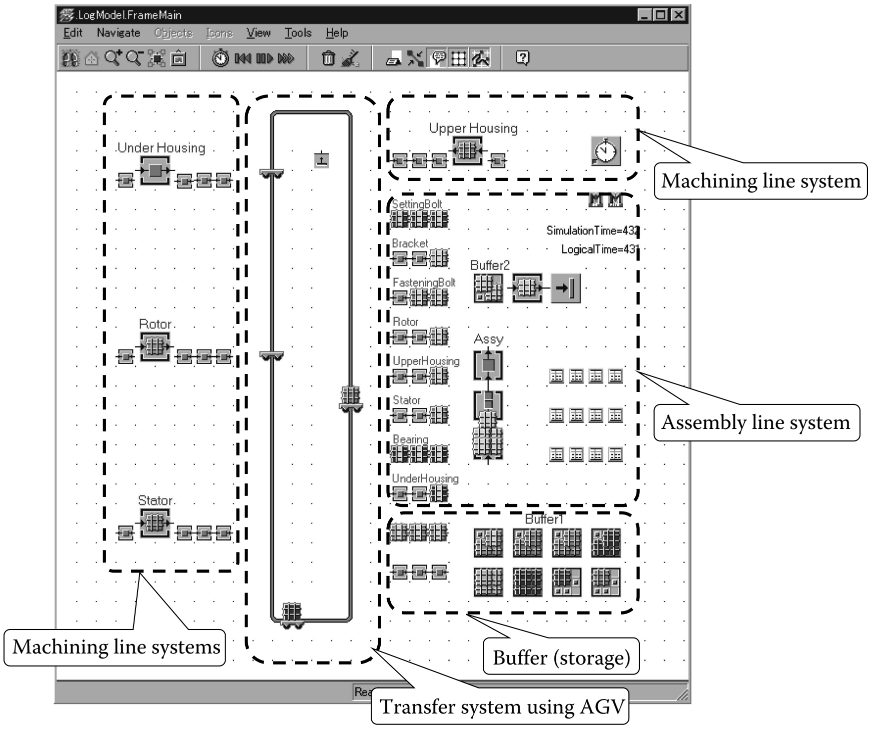


FIG. 24.16
Simulation model for transfer system using AGVs.

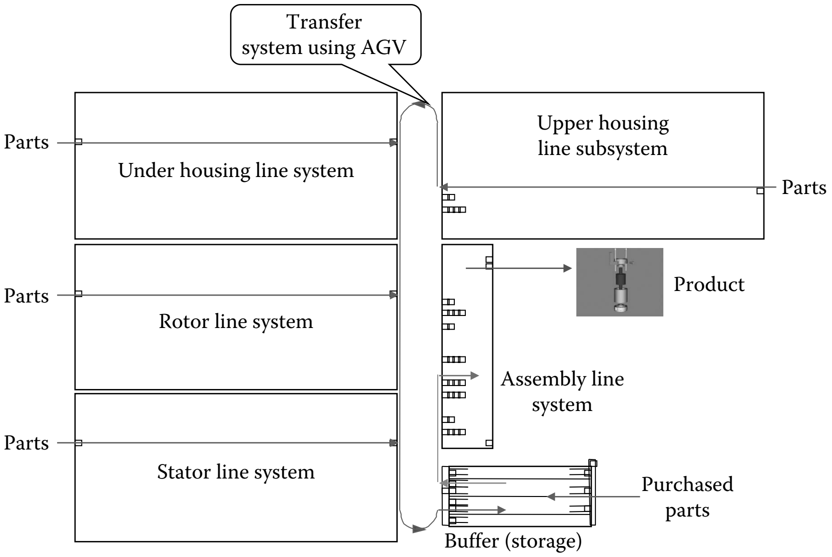


FIG. 24.17
Layout for hypothesis manufacturing system.

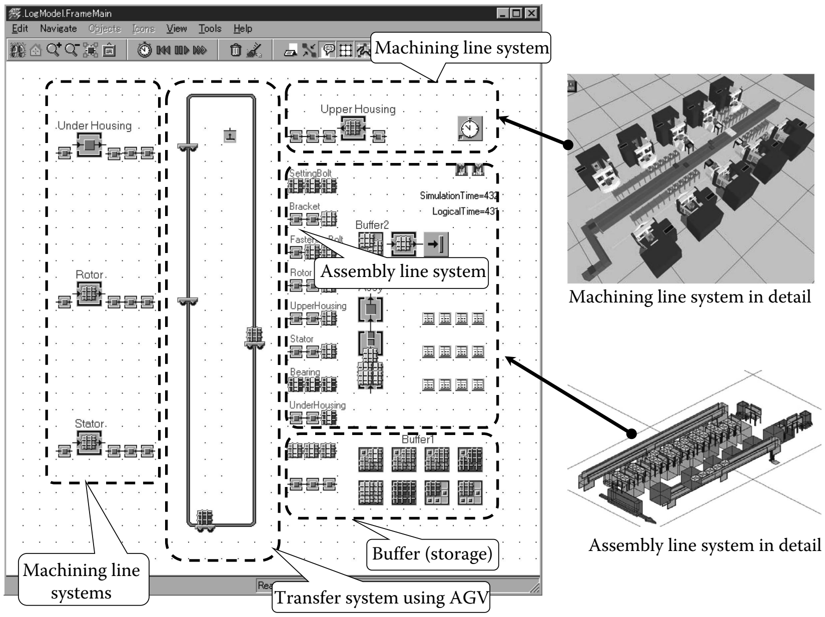


FIG. 24.18
Simulation model for hypothesis manufacturing system.

of inefficient productivity. Therefore, the designers usually evaluate the layout using the manufacturing system simulation while considering alternative layouts.

The following show an example for the layout design through the hypothesis manufacturing system that produces motors in Figure 24.15. Figure 24.17 shows the results of the layout. In the manufacturing process design, there are mainly three designs as the line system design, the transfer system design, and the layout design as in Figure 24.1. These three designs are often operated concurrently. For example, in the upper housing line system design and the assembly line system design, the layout of the upper housing line system is designed and proposed using the manufacturing system simulation. The upper housing line system is FMS. In the transfer system design, the layout of the transfer system is also designed and proposed. The layout design is fixed, synchronizing the line system design, the transfer system design. Figure 24.18 shows the simulation models for the manufacturing system.

In the layout design, the designer mainly determines the following items:

- Line system location
- Type of transfer system
- Transfer system location

- Capacity of production such as throughput, working rates in line system and transfer system
- Capital investments
- Flexibility and influence for line system location changes in response to brand new product that will be produced in the future

MANUFACTURING SYSTEM EMULATION IN IMPLEMENTATION PHASE

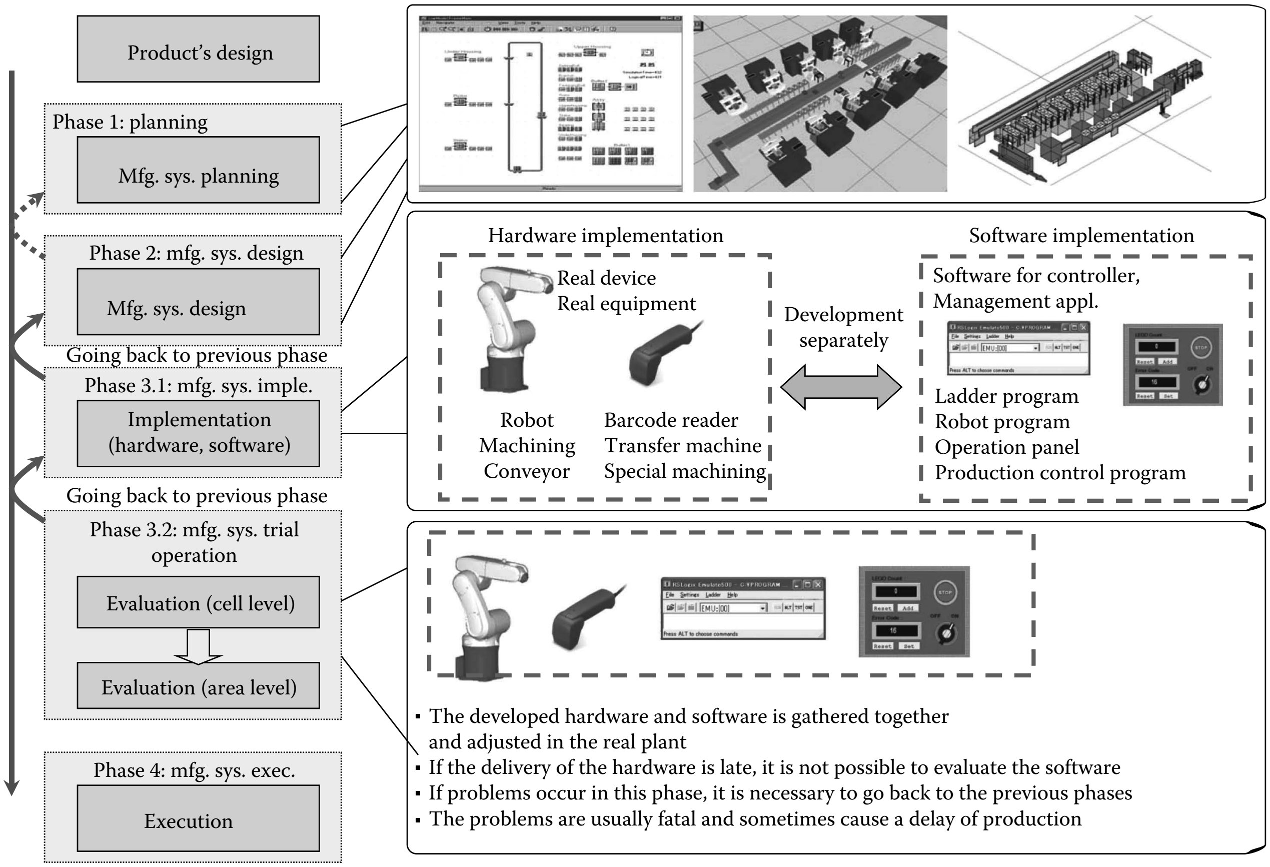
The typical manufacturing engineering process consists of four phases that are described in chapters. Figure 24.19 shows a typical implementation on manufacturing engineering processes. Phase 3 is the manufacturing system implementation phase to establish the manufacturing system in response to the manufacturing specifications.

Phase 3 is classified into two sub-phases.

Phase 3.1 is a period prior to the manufacturing system implementation phase. In this period, engineers implement hardware such as special machines, transfer machines, and software such as ladder programs, robot programs, operation panels, and production control programs.

Phase 3.2 is a later period of the manufacturing system implementation phase. In this period, in order to undertake the manufacturing system trial operations, engineers partially operate hardware execution and software execution and accurately evaluate their executions from the viewpoints of the manufacturing systems.

In phase 3.1, engineers separately develop hardware such as robots and special machining devices, and software such as ladder programs and production control programs. Then, they independently evaluate their developed hardware or software in house. The hardware and software are often developed in outside companies. In phase 3.2, the developed hardware or software is gathered together and adjusted in the factory. If the delivery of the hardware is late, it is not possible to evaluate the software. If problems occur in this phase, it is necessary to go back to the previous phases. The problems are usually serious and sometimes cause a delay in production. Therefore, industries needed suitable simulation technology advances in this phase. Recently, the manufacturing system emulation technologies have been proposed and developed. The system emulation provides methods to partially operate hardware execution and software execution and to accurately evaluate their executions from the viewpoints of manufacturing systems. The manufacturing system emulation realizes that under a condition where parts of equipment, control programs, and production management applications are not provided in a system, it is found by mixing and synchronizing



- The developed hardware and software is gathered together and adjusted in the real plant
- If the delivery of the hardware is late, it is not possible to evaluate the software
- If problems occur in this phase, it is necessary to go back to the previous phases
- The problems are usually fatal and sometimes cause a delay of production

FIG. 24.19
Manufacturing implementation on manufacturing engineering process.

the manufacturing system emulators, real equipment, real controllers, and production management applications. The main purposes of the manufacturing emulation are to make and improve the control programs such as ladder programs, robot programs, and to guarantee interoperability between equipment, the control programs, and the management applications. Using the manufacturing emulation, the wasteful periods are limited to the minimum by reducing the number of times needed to go back and refine the designs.

The typical functions in the manufacturing system emulation show the following:

1. An emulator function to emulate manufacturing cell behaviors by using data from a real world, which consists of the real equipment, real controllers, and management applications
2. A wiring function to logically wire the real-world data, the data on an emulator world implementing the emulator function, and data on manufacturing management applications
3. A transmission function to transmit the signals and the data between the emulator world and the real world without considering the differences between the real controllers and the emulators
4. A network interface function to connect the real controller and the emulators in a standard manner

Technical Research Institute of Japan Society for the Promotion of Machine Industry (TRI-JSPMI) developed the manufacturing system emulation.

The following shows the development manufacturing system emulation and a case study using the emulation.

In order to realize the typical functions, TRI-JSPMI proposed a manufacturing cell emulator to accomplish Function 1, and a soft wiring system to perform Function 2. The manufacturing cell emulator emulates mechanical behavior in accordance with signals from the soft wiring system.

Functions 3 and 4 are achieved by Open Resource interface for the Network/Open Robot interface for the Network (ORiN). ORiN is an industrial middleware based on an object-oriented technology. It provides a standard access method to controllers.

ORiN consists of two sections, an engine and a provider. The ORiN engine provides the application interfaces and some sophisticated common functions. The ORiN provides abstracted equipment models that are able to resolve the differences between abstracted equipment and real equipment. The ORiN specification defines many varieties of equipment interfaces as the providers. The applications on ORiN operate equipment through the providers via the ORiN engine.

The soft wiring system and the manufacturing cell emulator are running on ORiN. Figure 24.20 shows the system architecture of the emulation. Figure 24.21 presents the ORiN architecture.

Case Study

This case study is a hypothetical case of a small size of a manufacturing cell that consists of a robot, a tester, a palletizer, and a conveyor. This case study consists of a robot controller, a barcode reader, and a palletizer as real equipment. A PLC emulator and operation panel emulator are also connected. On the other hand, there are four systems, a production control system, manufacturing cell emulator, soft wiring system, and working monitoring system. The production control system and the working monitoring system are real systems running in the actual manufacturing system. Figure 24.22 shows the case study models of the manufacturing cell emulator using 3D-CAD information.

Figure 24.23 presents one of the typical procedures in this case study.

1. The barcode reader receives production order information by a Kanban.
2. The production control system receives the production order information via ORiN.
3. The production control system indicates the need to investigate the quantity of a product along with the

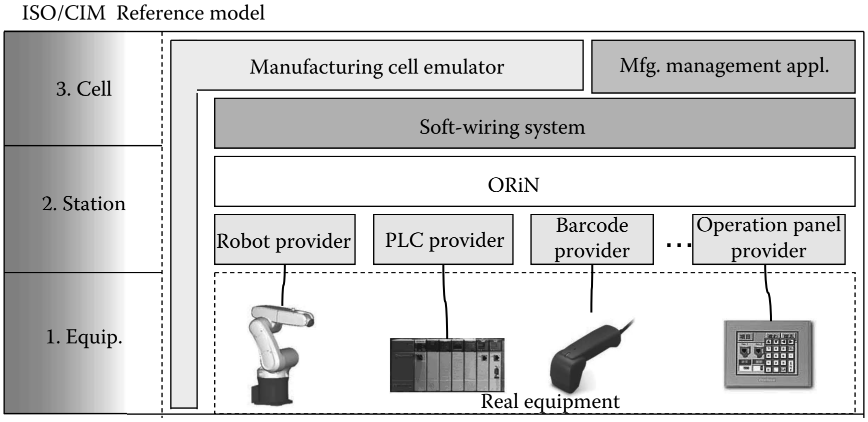


FIG. 24.20
System architecture of manufacturing system emulation.

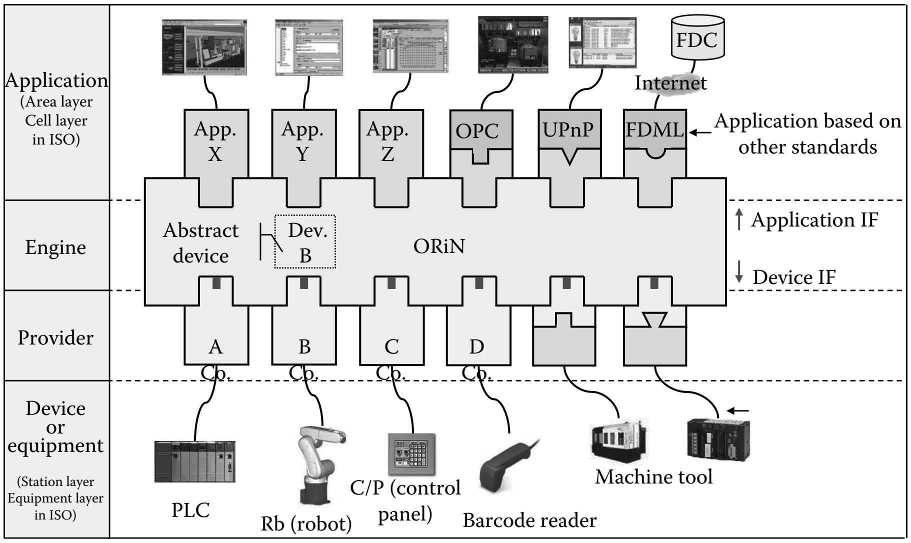


FIG. 24.21
ORiN architecture.

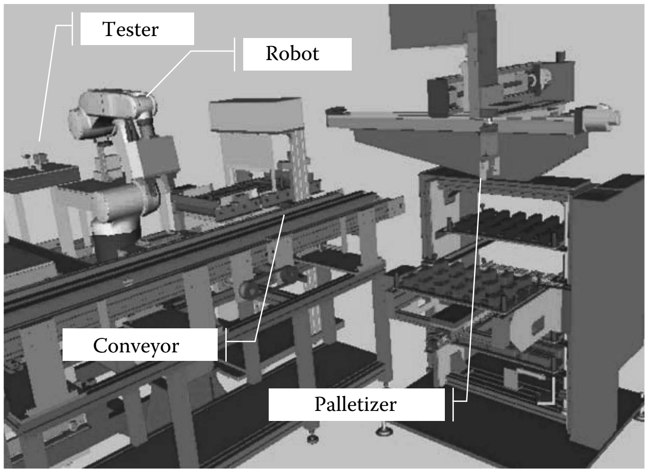
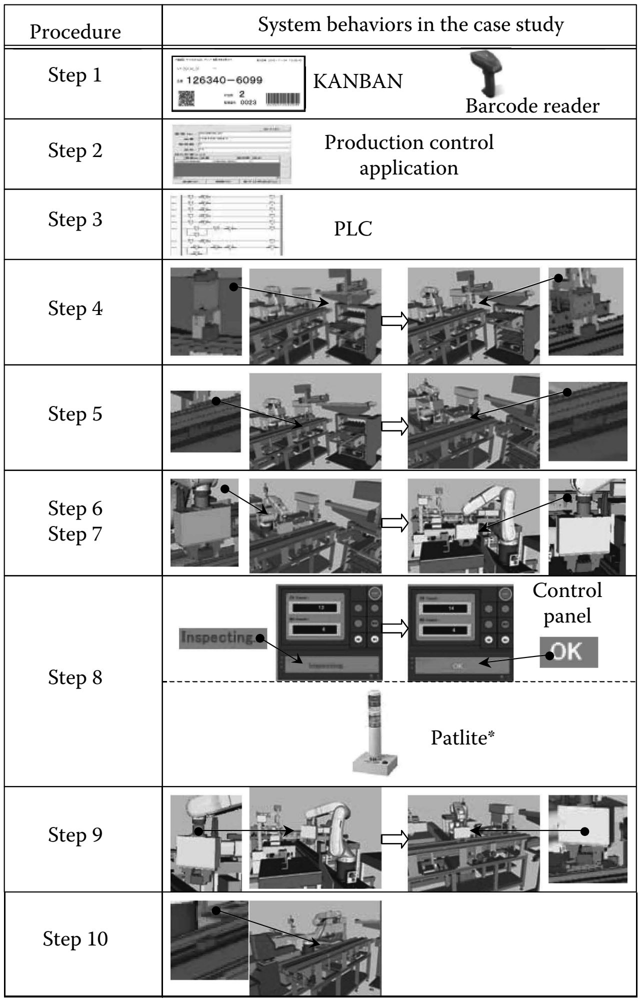


FIG. 24.22
Case study model of manufacturing system emulation using 3D-CAD information.

production order information toward the PLC via the soft wiring system.

4. The assigned product is picked up and moved to the conveyor by the palletizer in the emulator. These behaviors are controlled by the PLC via the soft wiring system.
5. The assigned product is translated to a position in front of the robot by the conveyor in the emulator. This behavior is controlled by the PLC via the soft wiring system.
6. The assigned product is picked up and moved to the tester by the robot. These behaviors are controlled by the PLC and the robot controller via ORiN.
7. The assigned product is investigated by the tester in the emulator.



Procedure	System behaviors in the case study
Step 1	126340−6099 KANBAN Barcode reader
Step 2	Production control application
Step 3	PLC
Step 4	
Step 5	
Step 6 Step 7	
Step 8	Inspecting Control panel OK Patlite*
Step 9	
Step 10	

FIG. 24.23
Typical procedure in the case study.

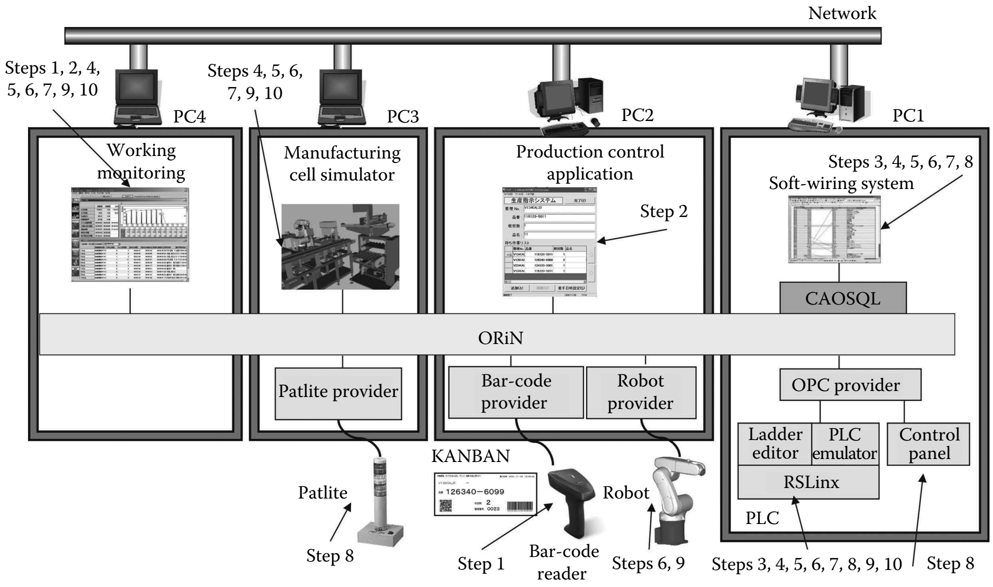


FIG. 24.24
System structure of the case study.

8. Results of this investigation in the emulator are sent to the PLC via the soft wiring system. Then, the control panel displays the results via the PLC. The patlite shows warning signs along the results via the PLC.
9. The assigned product is picked up and moved from the tester to the conveyor by the robot. These behaviors are controlled by the PLC and the robot controller via ORiN.
10. The assigned product is translated to a position to the end of conveyor by the conveyor in the emulator. This behavior is controlled by the PLC via the soft wiring system.
11. The assigned product after evaluation is eliminated in the emulator.

Figure 24.24 shows the system structure of this case study.

In this case study, the emulator world and the real world can be combined and synchronized using the emulator, the real equipment, the real controllers, and management applications. Verification of the facility control programs such as a ladder program in the PLC can also be confirmed by combining and synchronizing the emulator world and the real world. Practical usages of manufacturing management applications such as a working monitoring application can also be confirmed by combining and synchronizing the emulator world and the real world.

Through this case study, the manufacturing system emulation can be used in the implementation phase. The manufacturing system emulation is a valid to provide more efficient manufacturing system implementation during the implementation phase.

Currently, several manufacturing system emulators are proposed and developed in the market. The emulators are advertised heavily but industries that make use of them are few. In the near future, usage will increase since the manufacturing system emulation has the potential to be core technology in the manufacturing system engineering.

SUMMARY

This section describes manufacturing engineering process using simulation and emulation. In this chapter, one can see that the manufacturing system simulation and emulation have potential to be core technologies in the manufacturing systems.

Recently, the product data management and the product life cycle management are proposed by the software vendors that develop and provide 3D-CAD software. The vendors are interested in close relationships between 3D-CAD information and manufacturing system simulation or emulation. In the near future, they would realize to have the relationships closely.

Recently, the concurrent engineering, which means to design concurrently manufacturing systems with several engineers separately, has become important. At present, it is very difficult to combine different models that are made by different simulators because there are no standard descriptions for simulation models and a standard language for simulation programs has not been developed. Therefore, designers cannot cooperate easily when using different simulator models. The distributed simulation technologies are getting important. The distributed simulation is defined as executing a simulation while connecting and synchronizing several different simulators. The distributed simulation technologies for the manufacturing system simulation were developed and proposed in the academic levels. In the near future, the distributed simulation technologies will significantly support the concurrent engineering.

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